

# Estimating Air Pollution Infiltration Efficiencies for Exposure Assessment and Epidemiology

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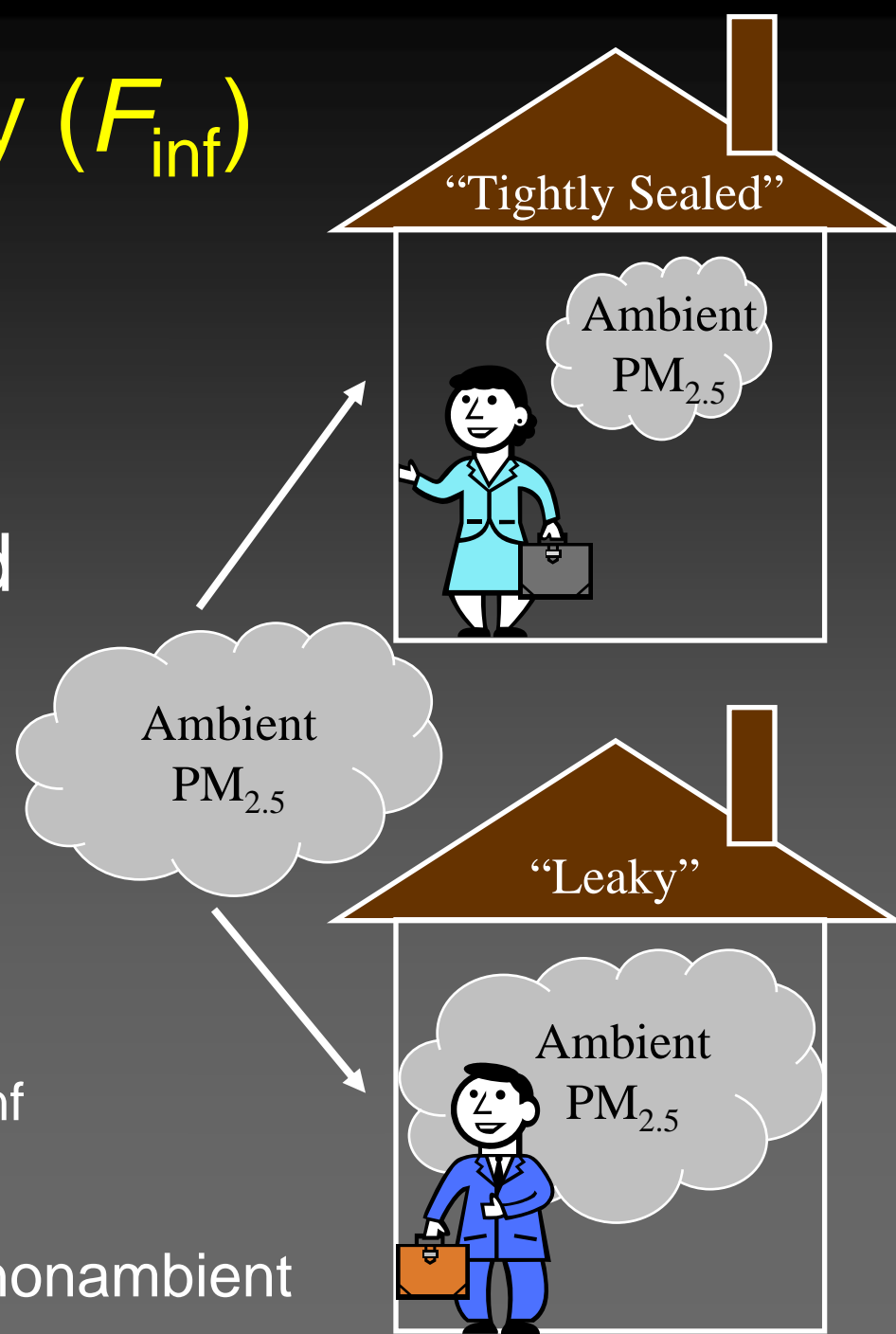
Burnaby, BC

# Overview

- Why estimate residential infiltration efficiencies?
- How?
  - Tracer
  - Recursive model
    - Description, validation, examples
- Application to epi
  - Panel studies
  - Model building for other study designs
- Windsor results
  - And possible future directions

# Infiltration Efficiency ( $F_{inf}$ )

- The fraction of the ambient concentration that penetrates indoors and remains suspended
- Function of AER, penetration, deposition
- Exposure to ambient pollution depends on  $F_{inf}$  & time spent outdoors
  - Total exposure = ambient + nonambient



# Why?

- To better interpret epi. results from different locations and/or from different seasons
- Reduce exposure misclassification in epi studies
- To tease apart health impacts of ambient vs. nonambient pollution

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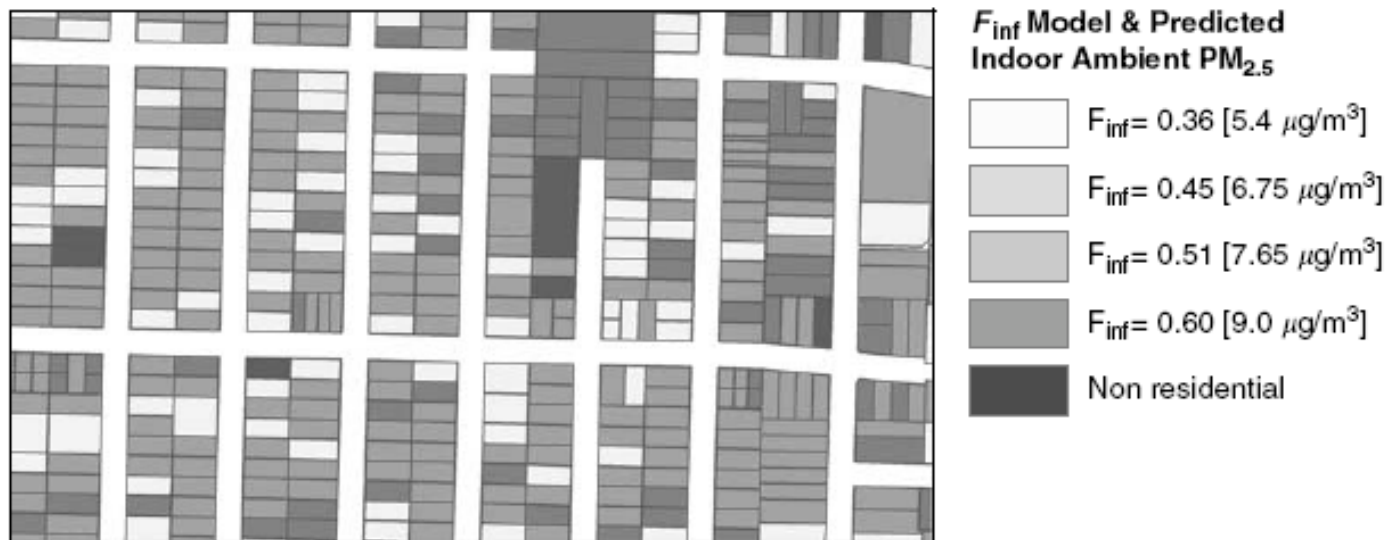
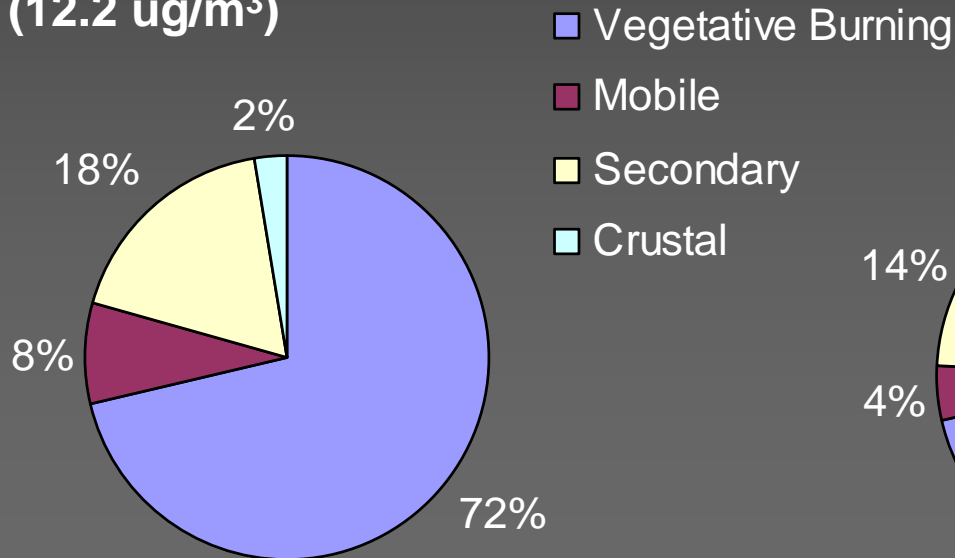


Figure 4.  $F_{inf}$  detached model results in the heating season and predicted indoor ambient  $PM_{2.5}$  from outdoor ambient concentrations ( $15 \mu\text{g}/\text{m}^3$ ).

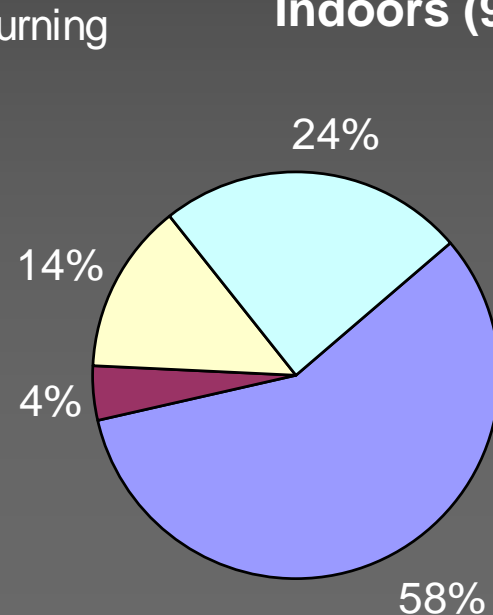
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**Outdoors (12.2 ug/m<sup>3</sup>)**



**Indoors (9.4 ug/m<sup>3</sup>)**



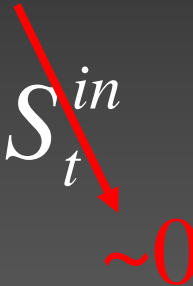
# How?

- Tracer (most commonly sulfur or sulfate)
  - Requires that there be no (or few) indoor or personal sources
  - Indoor/outdoor ratio or slope gives  $F_{inf}$
- Recursive model
  - Requires continuous indoor/outdoor measurements (e.g. nephelometer, DustTrak)
  - Does not require absence of indoor sources
  - Shows promise for estimating  $F_{inf}$  of pollutants without good tracers (e.g. ultrafines)

# Recursive Model Technique

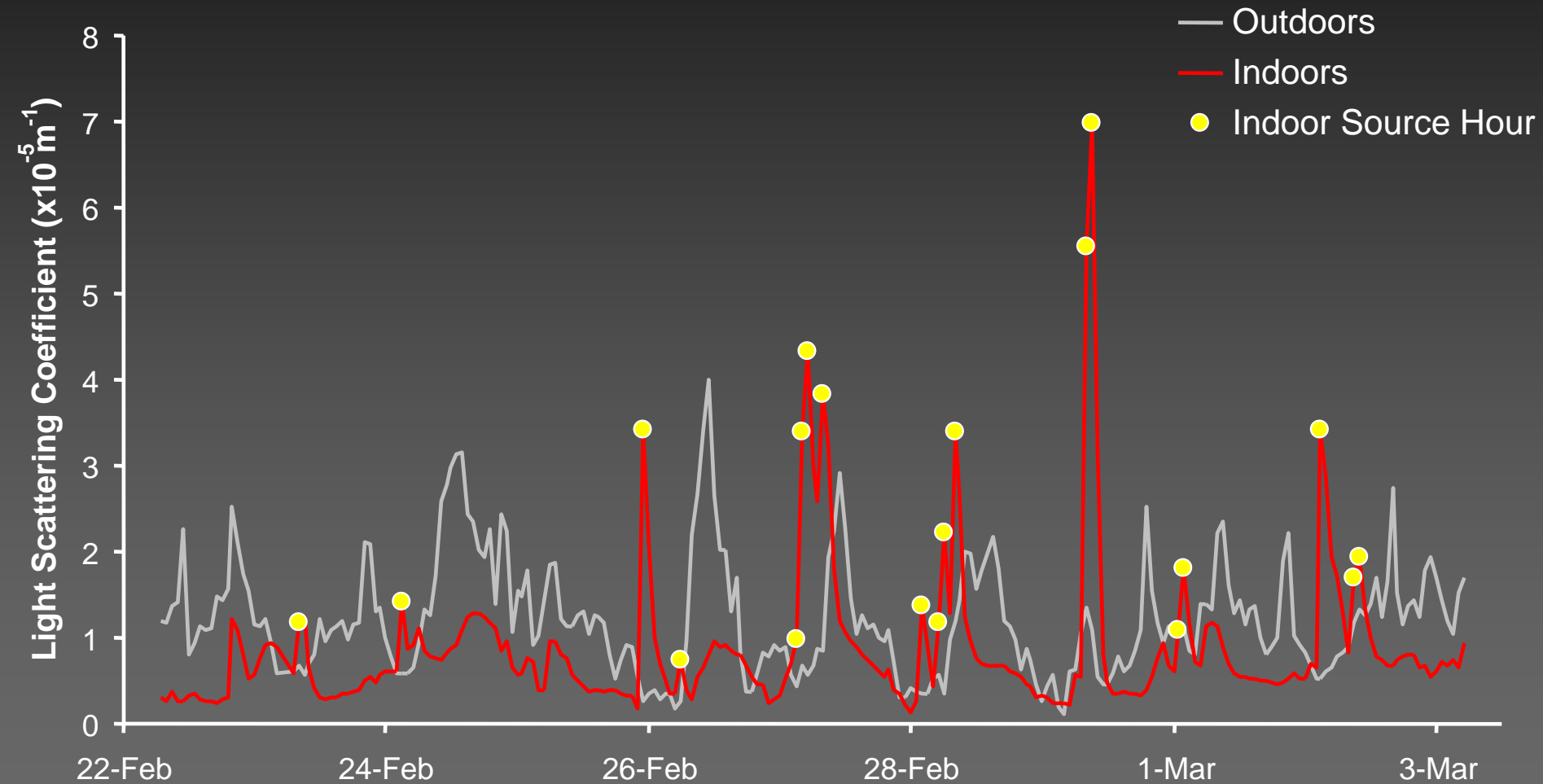
Average **indoor concentration** during the hour = Some fraction of the average **outdoor concentration** during the hour + Some fraction of the **indoor concentration** that remains from the PREVIOUS hour + Contribution from **indoor sources** during the hour

$$C_t^{in} = \beta_1 C_t^{out} + \beta_2 C_{t-1}^{in} + S_t^{in}$$

  $\sim 0$

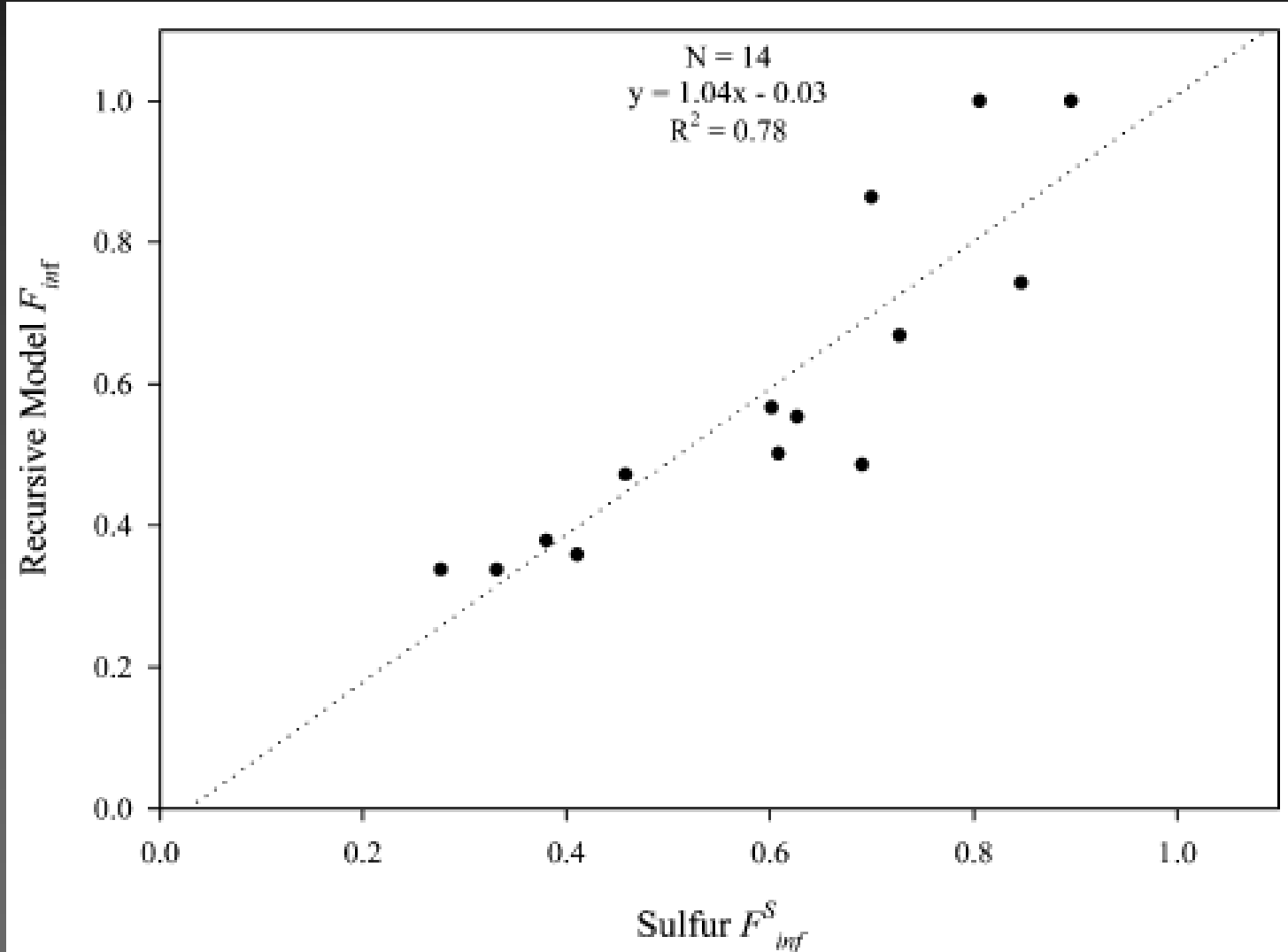
$$F_{inf} = \frac{Pa}{a+k} = \frac{\beta_1}{1-\beta_2}$$

# Recursive Model Technique



# Recursive Model Technique

## Validation



# Recursive Model Technique

## Validation

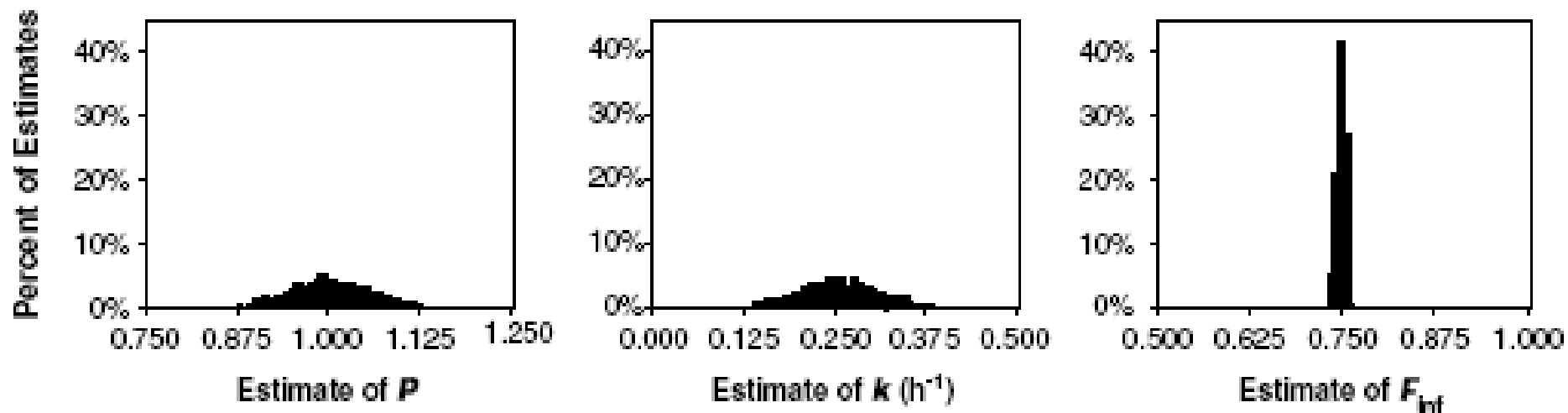
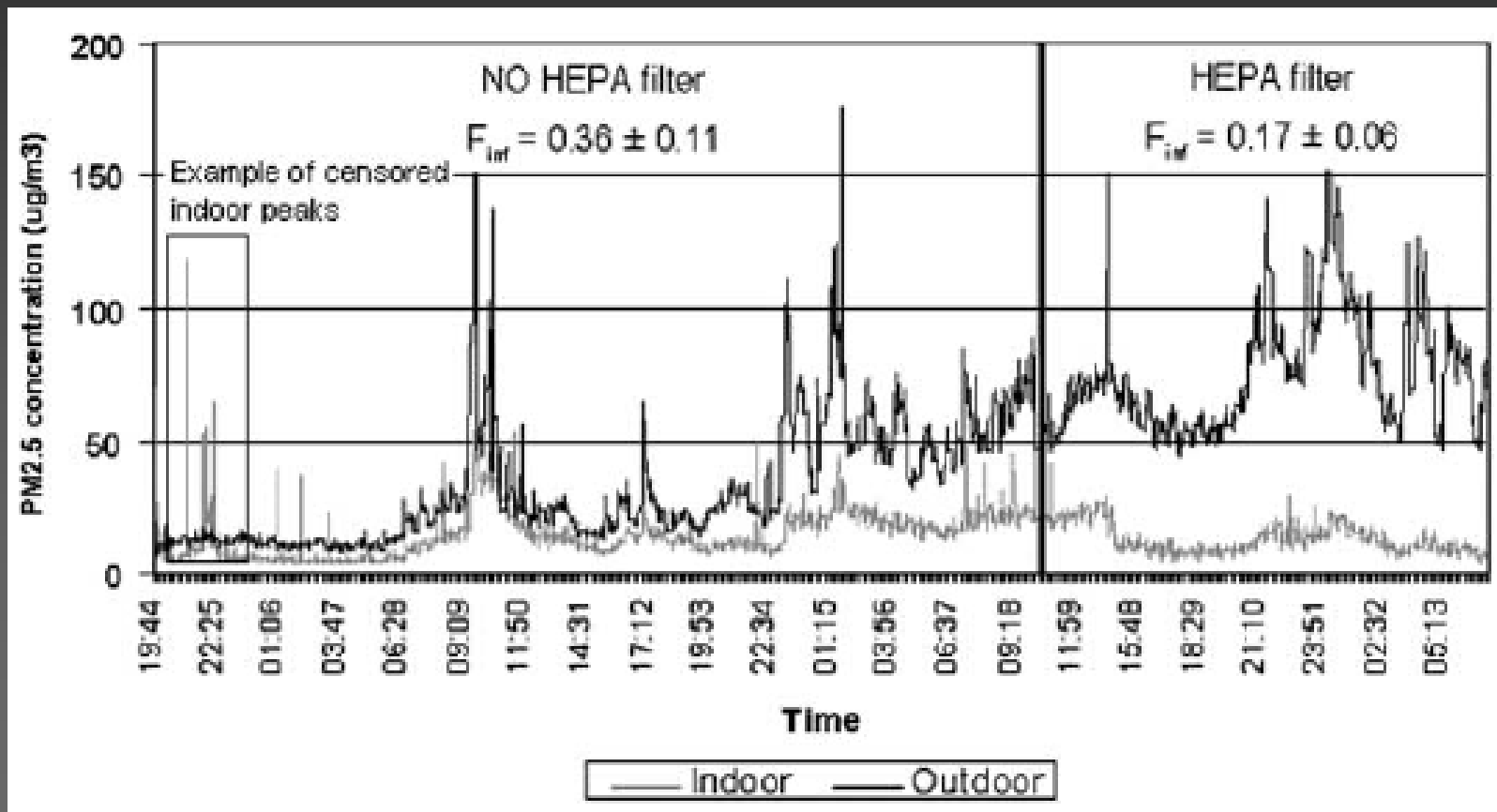


Figure 3. Distributions of 1000 estimates of  $P$ ,  $k$ , and  $F_{\text{inf}}$  at 5% measurement error. True values used in simulations were  $P = 1.00$ ,  $k = 0.25 \text{ h}^{-1}$ , and  $F_{\text{inf}} = 0.75$ .

# Recursive Model Technique

## Examples

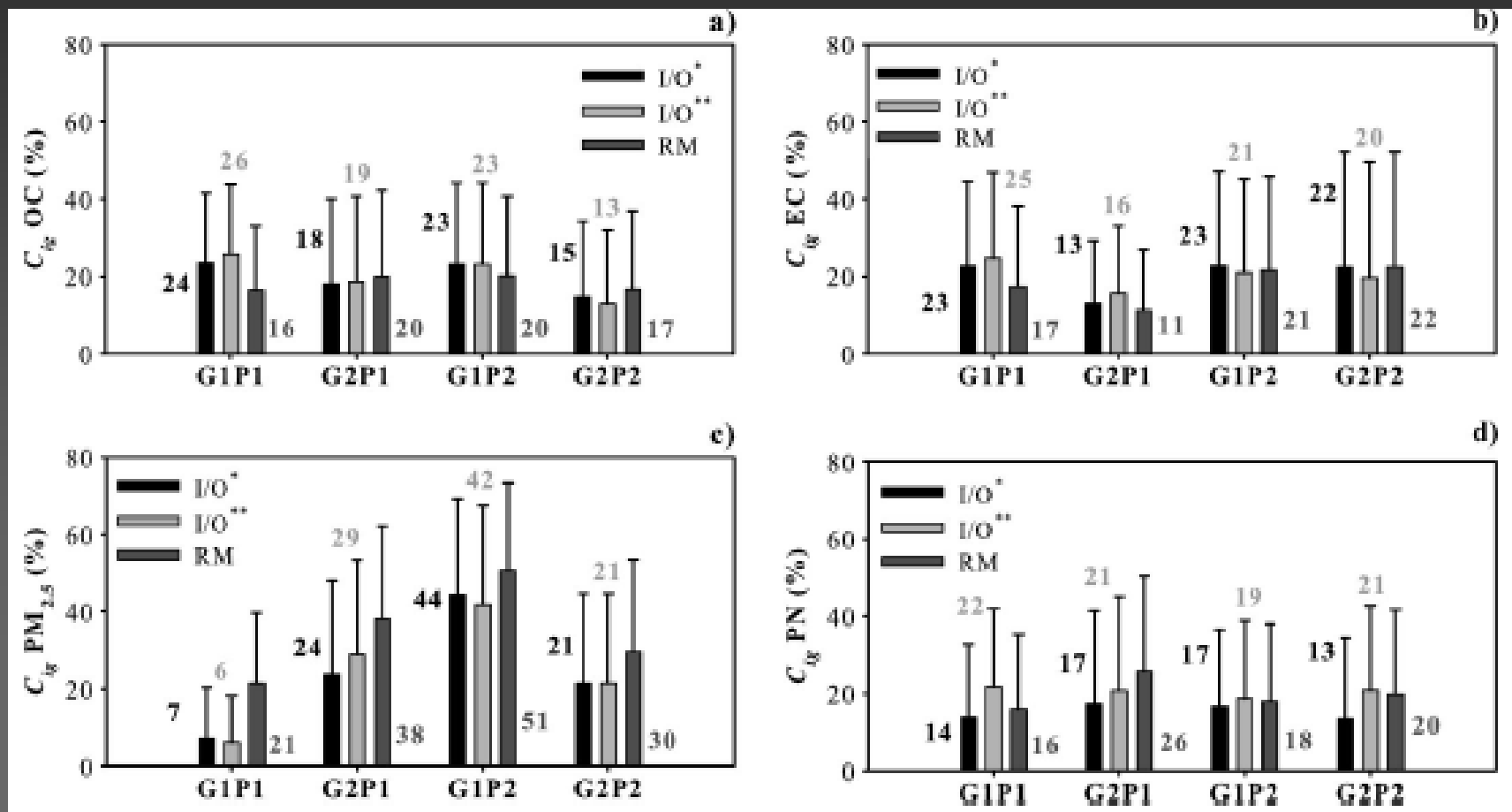
- Air cleaner effectiveness in woodsmoke and forest fire impacted community



# Recursive Model Technique

## Examples

- Contributions of ambient and nonambient sources at retirement facilities in southern CA



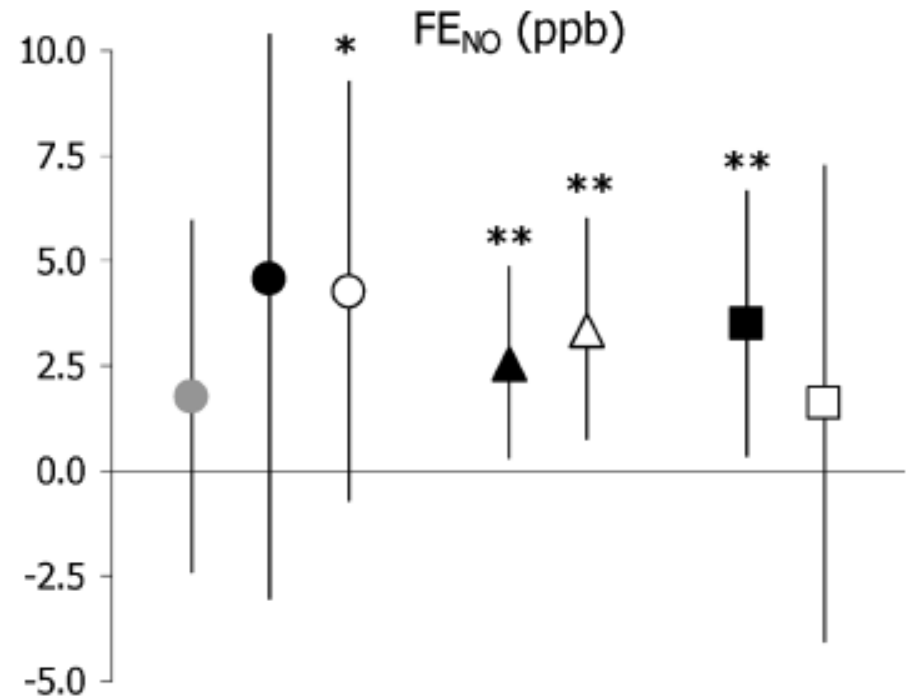
# Application of $F_{inf}$ to Epidemiology

## Panel Studies

- Ambient Levoglucosan
- Ambient Light Absorbing Carbon
- Ambient  $PM_{2.5}$
- ▲ Personal Light Absorbing Carbon
- △ Personal  $PM_{2.5}$
- Ambient-Generated  $PM_{2.5}$
- Nonambient  $PM_{2.5}$

\*\*  $p < 0.05$

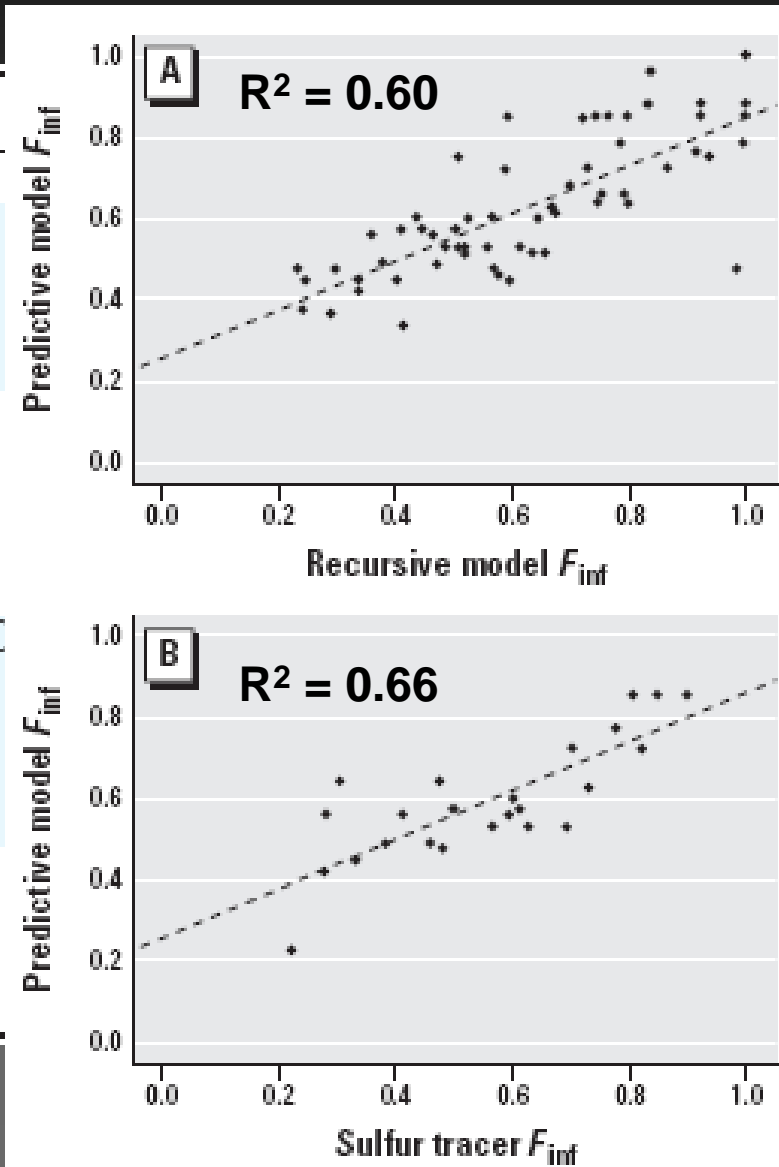
\*  $p < 0.10$



# Application of $F_{inf}$ to Epidemiology

## Model Development for Large Studies

Parameter
Intercept
Residence type
Private home (reference)
Private apartment
Group home
Air cleaner
None (reference)
Ion generator
Filter
Electrostatic precipitator
Average outdoor temperature (°C)
< 4 (reference)
4–8
8–12
≥ 12
Average daily rainfall (inches) <sup>b</sup>
< 0.5 (reference)
0.05–0.1
> 0.1



95% CI	$p$ -Value
1.28 to 0.54	< 0.001
1.08 to 0.14	0.61
1.07 to 0.31	< 0.01
1.16 to 0.02	0.14
1.22 to 0.05	0.23
1.22 to 0.00	0.05
1.06 to 0.32	< 0.01
1.18 to 0.45	< 0.001
1.31 to 0.58	< 0.001
1.16 to 0.02	0.13
1.26 to -0.04	< 0.01

# Application of $F_{inf}$ to Epidemiology

## Model Development for Large Studies

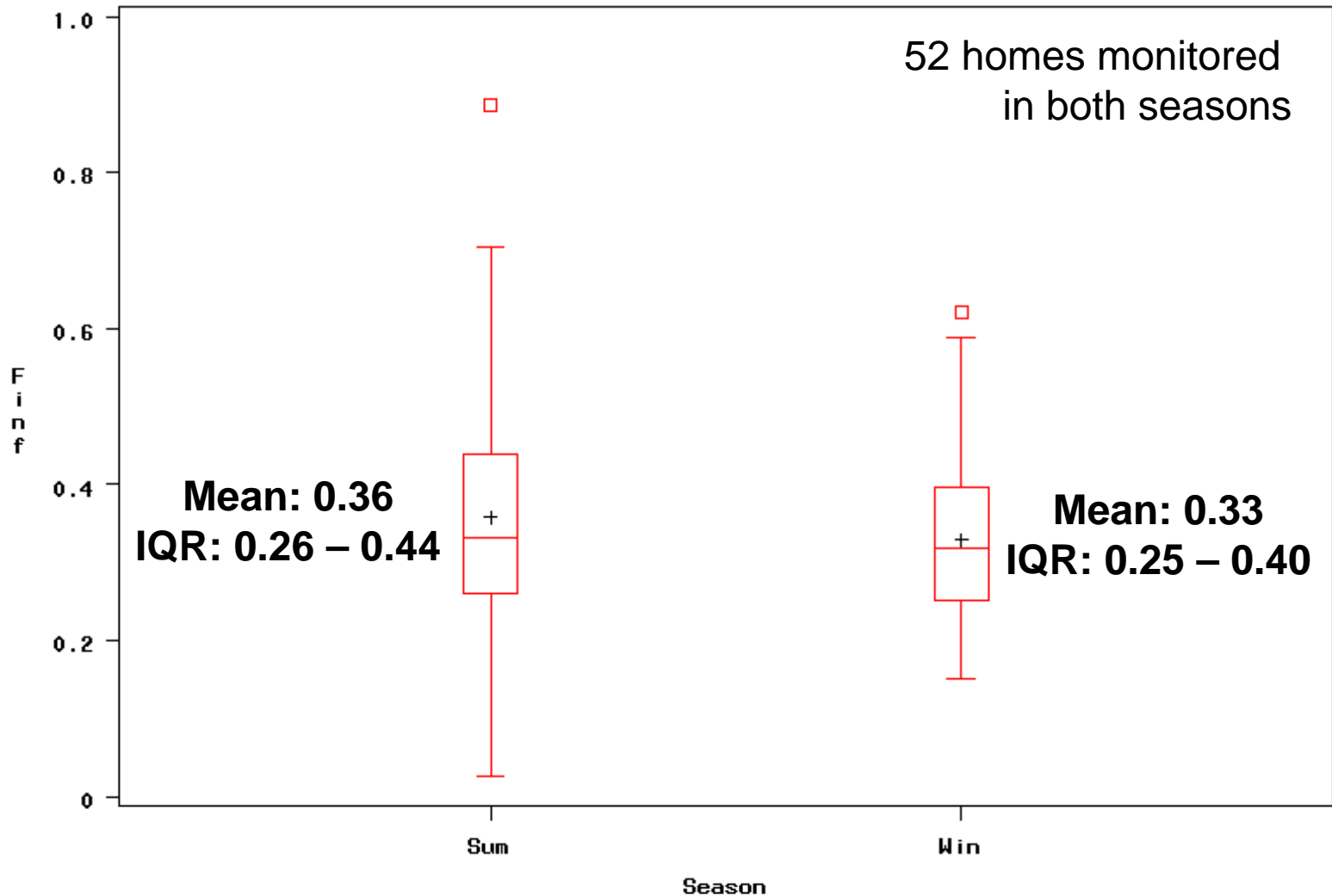
- Victoria, BC
- Spatial property assessment data (SPAD)
- Model including season predicts 54% of total variance
- Potentially allows  $F_{inf}$  to be estimated in many homes without I/O monitoring

Table 4. Multiple regression model of  $F_{inf}$  during the heating season ( $n = 44$ ,  $R^2 = 0.37$ ).

Parameter	Estimate	SE	P-value
Intercept	0.36	0.03	< 0.00
<i>Improved value (&gt; median reference)</i>			
< Median	0.15	0.04	< 0.00
<i>Heating (no FHA reference)</i>			
FHA	0.09	0.04	0.01

Abbreviation: FHA, forced hot air.

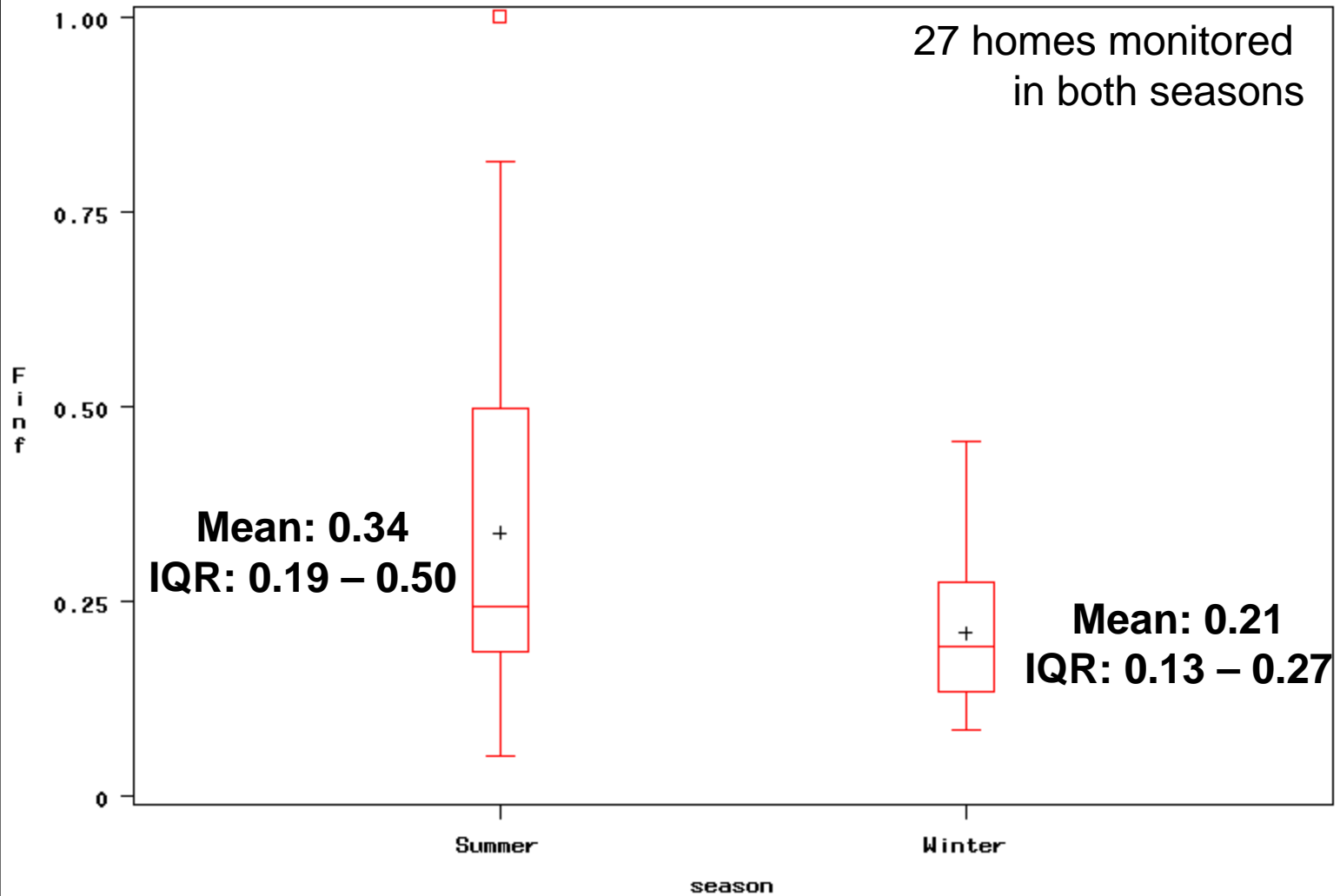
# Windsor $PM_{2.5} F_{inf}$



# Windsor $PM_{2.5}$ $F_{inf}$ Models

Season	Predictor(s)	$R^2$
Summer	I-O Temp Diff, Window Opening	0.36
Winter	Building age, air cleaner use	0.20

# Windsor UFP $F_{inf}$



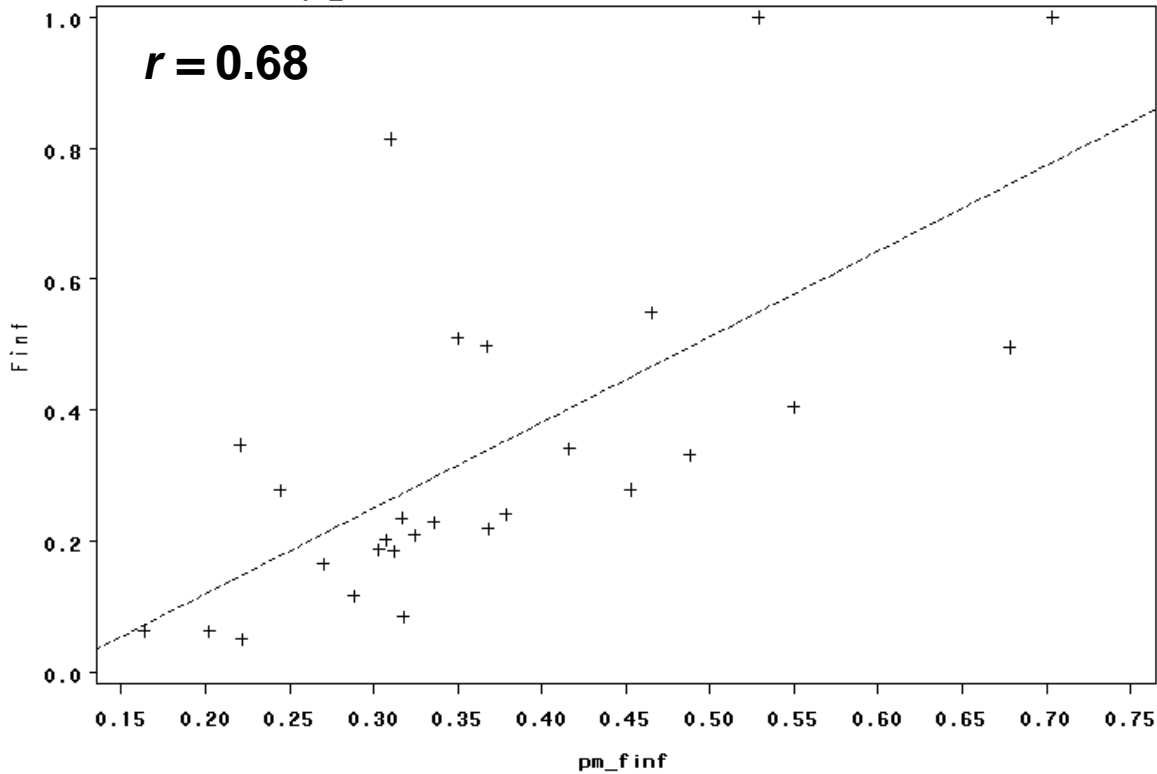
# Windsor UFP $F_{inf}$ Models

Season	Predictor(s)	R <sup>2</sup>
Summer	Outdoor Temp, Window Opening	0.56
Winter	-----	-----

# PM<sub>2</sub>

Season=Sum

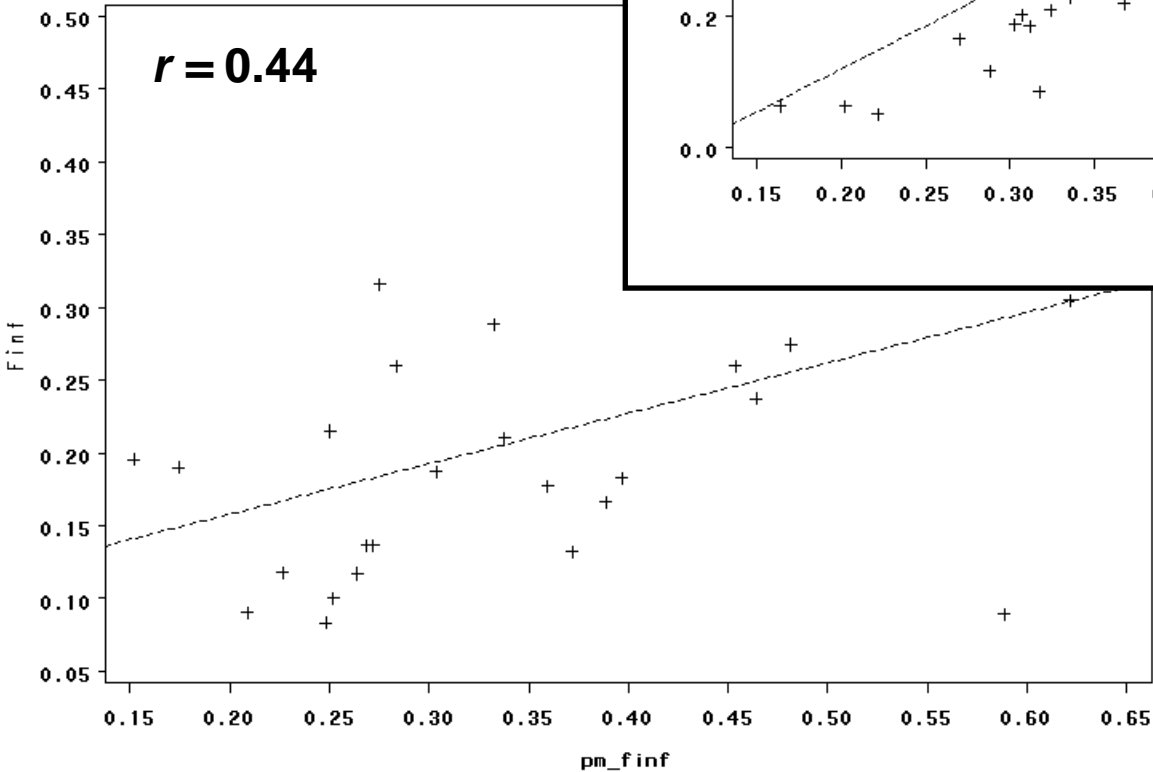
$$F_{inf} = -0.1415 + 1.3072 pm\_f_{inf}$$



N  
27  
Rsq  
0.4584  
AdjRsq  
0.4367  
RMSE  
0.1943

Season

$$F_{inf} = 0.0886 + 0.3465 pm\_f_{inf}$$



# Other Possibilities for Windsor Data

- Continue development of  $F_{inf}$  models
- Comparison of  $F_{inf}$  for different PM species
  - PM<sub>2.5</sub>
  - UFP
  - LAC
- Health effects
  - Ambient / nonambient PM vs. lung function